Celanese
CHEMICALS

Celvol Polyvinyl Alcohol

Celvol™ Polyvinyl Alcohol for Textile Warp Sizing

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Celvol™ Polyvinyl Alcohol for Textile Warp Sizing

Textiles is a major end use market for Celvol polyvinyl alcohol. While the primary end use for PVOH in textiles is warp sizing, other applications include hand builders for fabric finishing and adhesives for screen printing.

Overview

Historically, the value of a warp sizing material has been related to its effectiveness in protecting yarns from breakage due to the forces of weaving. During the weaving process, the yarns are subjected to three basic physical stresses. These are stretch, strain and abrasion. Although these forces exist in varying proportions depending upon the type of loom and the fabric styling, all three are forces that must be considered in all cases.

Therefore, the ideal sizing material would produce a smooth, tough, elastic film which would adhere to the yarn. Smooth to minimize friction and abrasion. Tough to endure the load or strain. Elastic to allow flexibility and sufficient stretch.

The broad Celvol product line allows us to select the optimum grade rather than a compromise grade for your operation. Partially hydrolyzed grades are rapidly becoming the most widely used polyvinyl alcohols for warp sizing in the world.

Advantages of PVOH in Warp Sizing

Polyvinyl alcohol is the most widely used textile warp sizing composition. It is an excellent film former providing a protective coating for spun and filament yarn. Its tough film, however, is easily removed (desized) with hot water. Features of polyvinyl alcohol warp sizing include superior:

- Abrasion resistance
- Adhesion to synthetic fibers
- Flexibility/elongation
- Strength
- User friendly slashing performance

These features have led to improved warp sizing performance.

Improved Weavability

The abrasion resistance, elasticity and toughness of yarn sized with polyvinyl alcohol will lead to reductions in warp stop levels. This is particularly true on spun polyester blends where starch does not provide the required protection. Polyvinyl alcohol will also increase the weaving efficiency of 100% cotton fabrics woven on high-speed looms.

Low Add-On

Yarns sized with polyvinyl alcohol can run at lower add-ons because of the adhesion and strength advantage polyvinyl alcohol provides over natural binders. It can be effective at levels as low as one-third that of starch. Operating conditions in each mill will control the degree of starch replacements. Since the lower add on will take up less space on the yarn, it will contribute to improved weavability, particularly on high sley styles. In addition, lower add-ons will lead to several other benefits:

- Reduces size handling in the slasher room
- More yards on each beam
- Fewer slasher doffs
- Freight savings on greige cloth shipments
- Less size to remove at desizing, fewer chemicals to process in waste treatment

Less Shed

The excellent abrasion resistance and adhesion of polyvinyl alcohol to synthetic fibers means less shedding on the slasher and in the weave room. Since the electronic loom controls are adversely affected by shed, less shed will have favorable impact on loom operation. It will also minimize amount of yarn lost as waste. An additional benefit is reduction in labor required for cleaning.

Lower Weave Room Humidity

The inherent flexibility of films of polyvinyl alcohol resins eliminates the need for high relative humidity in the weave room. Humidities of 65-75% are recommended. Reduction in humidity should be done at a maximum rate of two percentage points every five days to acclimate loom parts and facilitate shed removal via vacuum, resulting in a cleaner weave room. It will provide more comfortable working conditions and lengthen the life of loom parts subject to corrosion.

Excellent Size Stability

Polyvinyl alcohol solutions are thermally stable and can be maintained for longer periods of time at elevated temperatures. This means that a major problem with starch – viscosity change on aging – is eliminated.

Resistance to Spoilage

Polyvinyl alcohol solutions are generally resistant to spoilage under conditions in the slashing and preparation areas. Size waste due to spoilage is eliminated, and resistance of greige goods to rot and mildew is increased.

TABLE 1
Hydrolysis Effect on Performance

Rating Scale: 1 = Good; 2 = Better; 3 = Best

	Fully Hydrolyzed	Intermediately Hydrolyzed	Partially Hydrolyzed
Yarn Type			
100% Cotton	1	1	2
Cotton-Polyester Blends	1	2	3
Wool	1	2	3
Rayon	1	2	3
Acrylic	1	2	3
Polypropylene	1	2	3
Nylon-Cotton Blends	1	2	3
Fiberglass	1	2	3
Size Preparation			
Dusting		Equal	
Resin Solubility	1	2	3
Viscosity Stability		Equal	
Lumping Avoidance	3	2	1
Slashing			
Ease of Split	1	2	3
Low Temperature Sizing	1	2	3
Hard Size Elimination	1	2	3
Foaming	3	2	1
High Pressure Squeeze		Equal	
Weaving			
Abrasion Resistance	1	2	3
Shedding Resistance	1	2	3
Finishing			
Desizability	1	2	3
Recoverability		Equal	
Environmental		Equal	

Recoverability

Polyvinyl alcohols are widely reclaimed and reused for sizing. Effluent levels from the finishing plant can be reduced, leading to improved compliance with local environmental standards. Sizing cost can be decreased via reduced consumption of virgin polyvinyl alcohol.

Choosing a Celvol Grade

Grade selection is dependent on many variables including yarn type and requirements for size preparation, slashing, weaving and finishing (Table 1).

Super Hydrolyzed Grades

All super hydrolyzed grades have 99.3% minimum hydrolysis. These grades have the highest water resistance, strength and abrasion resistance. However, since their high water resistance can result in potential desize problems, they are generally not recommended for warp sizing. They also tend to gel when their solutions are stored over long periods.

Fully Hydrolyzed Grades

These non-gelling grades have a 98.0 to 98.8% hydrolysis. Ease of preparation is a primary benefit for fully hydrolyzed grades which exhibit minimal tendency to lump or foam. Fully hydrolyzed grades are used for

TABLE 2
Celvol PVOH Grades for Warp Sizing

Grade	Hydrolysis, %	Viscosity, cps	Comment
Celvol 325	98.0-98.8	28-32	Exhibits minimal tendency to foam and lump when cooked. Used with starch for preparing fabrics containing 100% cotton yarns and reverse blend fabrics containing high levels of cotton. Preferred product for ground and pile warps and toweling.
Celvol 425	95.5-96.5	27-31	Balance of properties which lie between fully and partially hydrolyzed grades. Improved adhesion to polyester and other synthetic fibers versus Celvol 325.
Celvol 418	91.0-93.0	14.5-19.5	Best overall balance of properties for warp sizing. Significantly stronger than CMC and acrylic binders, with outstanding adhesion to both natural and synthetic fibers. Easily removed with hot water in the desize process.
Celvol 523	87.0-89.0	23-27	The acetate groups on the polymer chain provide superior adhesion to polyester and other synthetic fibers. Costly liquid binders, added to promote adhesion, are not required with Celvol 523. Provides best weaving and desizing performance. However, must add a defoamer to the size formulation to control foaming.
Celvol WS724	91.0-95.5	13-24	Similar in performance to Celvol 418. Product contains a defoamer to control foaming.
Celvol WS53NF	86.0-90.0	18.5-29.0	Similar in performance to Celvol 523. Product contains a defoamer to control foaming.

preparing fabrics containing 100% cotton yarns and reverse blend fabrics containing high levels of cotton. Celvol 325 polyvinyl alcohol, in particular, is a preferred product for ground and pile warps and toweling.

Intermediate Hydrolyzed Grades

These grades have a 95.5 to 97.5% hydrolysis range. Celvol 425 polyvinyl alcohol offers a balance of properties which lie in between fully and partially hydrolyzed grades. It provides improved adhesion to polyester and to other synthetic fibers.

Partially Hydrolyzed Grades

Partially hydrolyzed polyvinyl alcohols have an 87.0 to 90.0% hydrolysis range. The acetate groups on the polymer chain provide superior adhesion to polyester and other synthetic fibers. Costly liquid binders, added to promote adhesion, are unnecessary with partially hydrolyzed products. Conversion to a partially hydrolyzed grade generally leads to optimum weavability and desizability. Celvol 523 polyvinyl alcohol is the “workhorse” product of the Celvol product line.

Celvol 418

Celvol 418 is the newest grade of polyvinyl alcohol developed specifically for warp sizing (Table 2). It is significantly stronger than CMC and acrylic binders typically used in warp size, and it gives outstanding adhesion to natural and synthetic fibers. Some of the greatest benefits of Celvol 418 come in the finishing area – the product is easily removed with hot water, and like all polyvinyl alcohol grades, it is 100 percent biodegradable.

Typical properties of Celvol 418 polyvinyl alcohol are 91-93% hydrolysis and 14.5-19.5 cps (4% solution viscosity).

Yarn Type

All grades are commonly used to size spun yarns of 100% cotton and cotton-polyester blends. Partially hydrolyzed grades, due to their increased adhesion to synthetic fibers (Table 3), are preferred for sizing of yarns containing rayon, nylon, acrylic and polypropylene fibers. These products are also the favored size for 100% wool or woolen blend fabrics, since, with the use of a water soluble synthetic lubricant, they readily wash off in warm water (80-120 °F).

Lower viscosity partially hydrolyzed grades are used for sizing of filament yarn, including fiberglass.

Slashing

Compared with fully hydrolyzed grades, partially hydrolyzed grades exhibit weaker tensile strength (Figure 1).

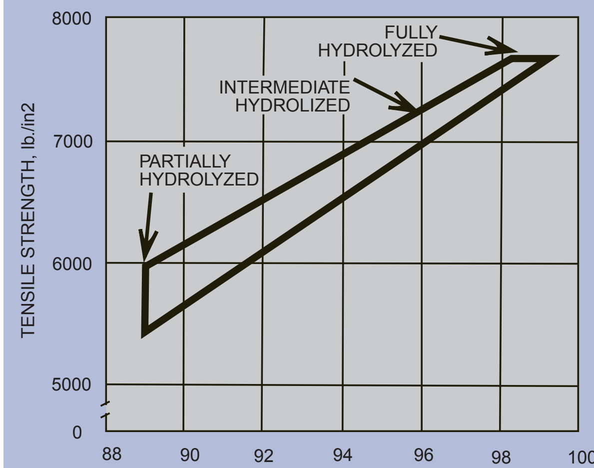
A weaker tensile strength is advantageous as it leads to an easier yarn split which minimizes disruption to the size film and, consequently, reduces yarn hairiness and decreases the number of ends out of lease. In addition, the easier split in combination with the improved adhesion of partially hydrolyzed grades will result in less shed on the slasher. Solutions of partially hydrolyzed grades can be run at lower temperatures (130 °F-170 °F, depending on the type of wax and its melt point), thus saving energy as well as

TABLE 3
Adhesion to Synthetic Films*(g/mm²)

Film	Partially Hydrolyzed	Fully Hydrolyzed
Acetate	10.0	2.0
Nylon 6	11.0	6.0
Acrylic	9.0	4.0
Polyester	7.0	1.0

*Medium viscosity polyvinyl alcohol; films conditioned at 65° R. H., 20 °C. Reference: C. A. Finch

FIGURE 1
Polyvinyl Alcohol Film Tensile as a Function of Hydrolysis*



* Tensiles determined on Instron Tester:
1.7 mil dry film thickness equilibrated to 73 °F at 50% RH

creating a safer and more comfortable work environment for the slasher operator. Squeeze roll laps can be cut properly without fear of being scalded by hot size. Other advantages of low temperature sizing includes:

- Fewer slasher breakouts
- Alleviation of skin formation
- Elimination of hard size and stop marks
- Reduction of stretch on yarns

Partially hydrolyzed grades may foam more than fully hydrolyzed products. If increased foaming does occur, it can be controlled via addition of a defoamer. Contact your local Celanese representative if assistance is needed in this area.

Weaving

All polyvinyl alcohols can enhance the weavability of yarns by providing an excellent protective coating. The abrasion resistance of the partially hydrolyzed products is superior to that of the fully hydrolyzed products (Figure 2). This advantage in combination with their adhesion advantage will enhance weavability via:

- Lower loom stop levels
- Less shedding
- Lower add-ons
- Fewer warp related filling stops due to less hairy yarn

Finishing

a) Desize – In the production of woven cloth, ease of size removal in finishing is equally as important as in slashing and weaving. Films of partially hydrolyzed polyvinyl alcohols dissolve more readily than those of fully hydrolyzed grades, even when exposed to heat set conditions (Figure 3). Fully

FIGURE 2
Abrasion Resistance of Polyvinyl Alcohol Sized Yarn (8.5% Add-On)

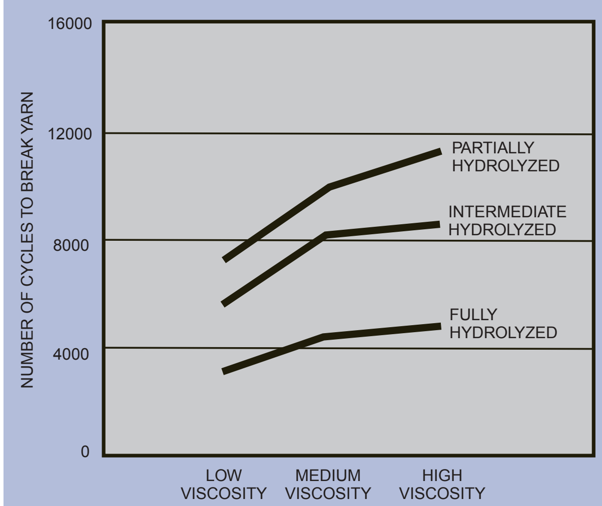
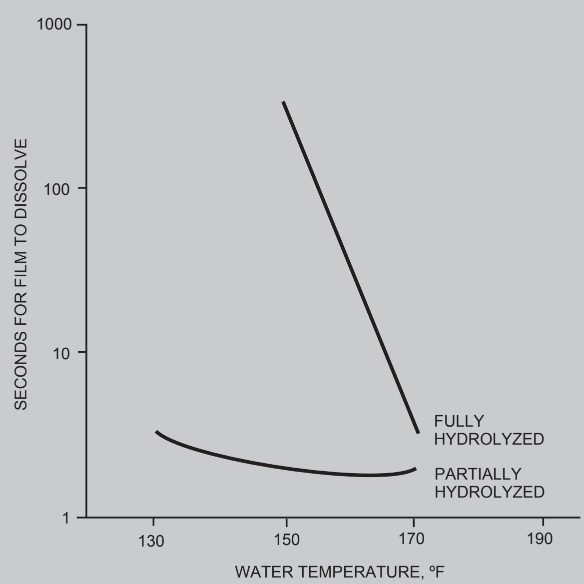


FIGURE 3
Film Solubility Rate for Films Heat Set at 400 °F for 30 Seconds



hydrolyzed grades will crystalize ("line up") under heat set conditions, causing increased hydrogen bonding (Figure 4). This is a tightly bound structure which will resist penetration of water.

The bulky acetate groups present on partially hydrolyzed products will minimize crystalization and consequent hydrogen bonding forces. The improved film solubility advantage is readily translated to advantages in cloth (Figure 5). Both partially and fully hydrolyzed grades are readily removed from polyester/cotton cloth with 180 °F water. However, as the desizing temperature is decreased, it becomes more difficult to remove the fully hydrolyzed product. Complete removal of partially hydrolyzed products from cloth has been demonstrated in laboratory tests at temperatures as low as 80 °F (without wax). In addition to energy savings via low temperature desizing, usage of partially hydrolyzed grades can lead to reductions by as much as 50% in water overflow rates. The later benefit will translate into decreased cost for effluent disposal and water usage. Improved fabric quality can also be expected with partially hydrolyzed polyvinyl alcohol, as there is less risk of residual size in fabric and its resulting adverse impact on dyeability.

b) Recovery – Although all polyvinyl alcohol products can be reclaimed for reuse in the greige mill, partially hydrolyzed grades are more easily removed from the fabric and higher solids are attainable in the desize feed solution to the ultra-filtration unit. Thus, there is a reduction in time required to reach the desired concentrate solids level.

FIGURE 4
Hydrogen Bonding of Polyvinyl Alcohol

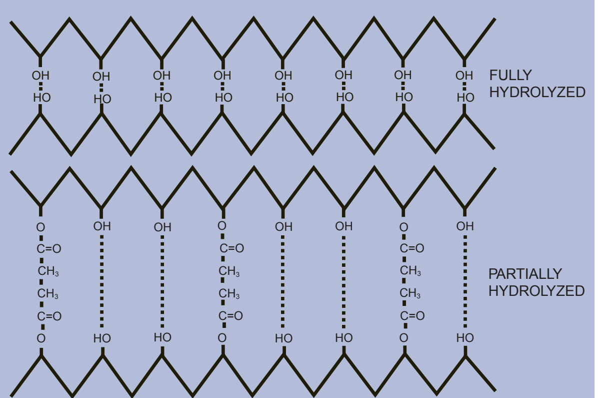
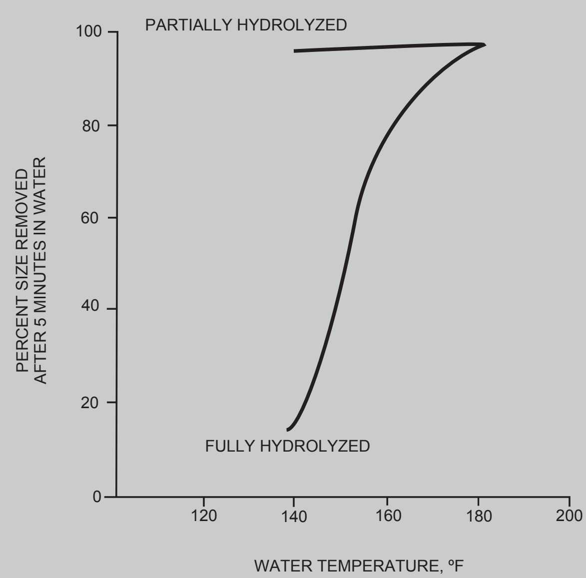


FIGURE 5
Removal of Polyvinyl Alcohol from PE/C Cloth Heat Set at 400 °F for 60 Seconds



Size Formulation Additives

"Simpler is better" is a good general rule of thumb for selecting a size formulation. For many applications, polyvinyl alcohol and wax will provide the optimal sizing performance. In some formulations, other ingredients are added to reduce costs, facilitate processing or improve final product properties. The most common modifiers are waxes, starches, antistats and defoamers. Brief overviews of some of these additives are provided below. For additional information, contact your Celanese representative.

Waxes

Several reasons are often cited for the inclusion of wax in a size formulation:

- Reduce dryer can sticking
- Weaken film for easier split
- Minimize clinging on looms
- Improve lubrication for the size coating

The most commonly used waxes are unmodified hydrogenated tallow glycerides (HTG). Modified waxes are also available which enhance specific performance attributes (e.g., dispersibility, antisticking, removal, etc.) for wax in size formulations. The recommended level is 5-10%, based on the weight of the film former (e.g., polyvinyl alcohol).

Excessive use of waxes can adversely affect the size film, causing:

- Poor adhesion
- Brittleness
- Roughness
- Decreased abrasion resistance

In addition, waxes can be difficult to remove and, consequently, residual wax in desized fabric can lead to significant quality problems. Hence, caution is recommended when choosing a wax level. To ensure efficient desizing, it is important to select a wax that contains an effective emulsifier. The emulsifier will act to prevent the wax from redepositing back on the fabric during desizing. Your Celanese representative will be happy to assist in determining your requirements for type and level of wax.

Starch

Starch is primarily used as an extender for polyvinyl alcohol to reduce formulation cost. Occasionally, it is used to weaken size film. Compared to polyvinyl alcohol, starch:

- Demonstrates poorer adhesion to synthetic fibers
- Requires a longer cooking cycle at higher temperatures
- Exhibits more shedding on slasher and loom
- Requires higher add-on levels

Many types of starch are used for warp sizing, ranging from the low cost pearl (unmodified) starch to the highly modified starch ethers (e.g., hydroxyethylated, carboxymethylated, etc.). Although the latter products are more expensive, they are preferred for blending with polyvinyl alcohol. They exhibit greater compatibility with polyvinyl alcohol, less tendency to shed, and increased viscosity stability.

Antistats

Antistats are needed with starch-containing formulations to minimize static on warp yarns. Generally, they are not needed with 100% polyvinyl alcohol sizes. Antistats function as humectants, helping to retain moisture in the film while simultaneously plasticizing the film. Commonly used antistats include urea, ethylene glycol and glycerol. Recommended level is 3-7% based on weight of the film former.

Defoamers

Size solutions can exhibit foam due to a variety of reasons, including water quality, spin finishes, chemical additives, and type of polyvinyl alcohol and starch. Low levels of foam are desirable to prevent skinning in the size box, particularly during creep speed. However, additional defoamer is sometimes required to control the level. The recommended level is 0.25-1.00% based on weight of the film former.

Recommended Defoamers

Product	Manufacturer
Foamblast 338	Ross Chemical
Harcross H-116FG	Harcross Chemical
Ultra 123E and 123F	Ultra Additives

Binders

Liquid binders have been used predominantly to improve adhesion of formulations based on starch and/or fully hydrolyzed polyvinyl alcohol. They are not required for partially hydrolyzed polyvinyl alcohols which possess superior adhesion to synthetic fibers. Two major types of binders are polyester and polyacrylic solutions (~25% solids). Binder films are somewhat tacky and care should be taken to minimize sticking on the slasher.

Size Formulations

Several starting formulations are shown in Table 4.

The solids in the base formulation can be adjusted to increase or decrease add-on. Contact your Celanese representative for a size formulation designed to meet your specific requirements.

TABLE 4
Suggested Starting Formulations

	Oxford Shirting	Sportswear	Percale Sheeting	Toweling (Ground Warp)
Fiber	40:60 P/C	50:50 P/R	50:50 P/C	100% Cotton
Yarn Count	42/1	20/1	35/1	10/1
Water, starting gal.*	200	220	215-285	325
Celvol, pounds	300	150	300	350
Wax, pounds	24	23	27	35
Solids (%)	14	6	10-13	10
Add-On (%)	12-15	7-9	10-15	13-16

P = Polyester, C = Cotton, R = Rayon

*Starting water volume depends on cooking set-up. Finished gallons should be measured to achieve desired solids level.

Slashing

Although specific slashing equipment and conditions will vary from mill to mill, there are some basic guidelines which are applicable to most slashing operations. Several "rules of thumb" are present in this section for your reference.

Warp Density/Sley

Overcrowding of yarns in the size box is a major source of quality and, consequently, weaving problems for slashed warps. If warp ends are too closely packed, there may be insufficient space between ends to allow adequate size liquid circulation. Only the top and bottom of the yarns will be wet, resulting in continuous liquid contact between adjacent ends during the drying process. As a result, a tough adhesive film forms across the entire sheet of warp yarns. When the dry size film splits, any tangled fibers will be torn apart. The resultant shedding and clinging in the loom causes end breaks, formation of "fuzz-balls," and production of seconds. For air-jet weaving this will cause warp related filling spots.

To avoid overcrowding in the size box, spacing should not exceed the recommended maximum warp density. For ring spun 100% cotton yarn, spacing between adjacent ends should not be less than the diameter of the yarn. For ring spun polyester-cotton blend yarn, spacing should not be less than 1.5 times the yarn diameter. For open end yarn, recommended number of ends per inch is 10% less than that for ring spun yarn of comparable count.

Maximum warp density for individual yarn counts is shown in Table 5.

To determine maximum ends per size box, multiply the recommended

TABLE 5
Maximum Warp Density Vs. Yarn Count

	Maximum Ends/Inch in Size Box	
Yarn Count	Ring Spun	Open End
10	35	31
20	50	45
25	56	50
30	62	56
35	66	60
40	71	64
50	80	72

maximum ends/inch by actual distance between the flanges on the section beam. Use more spacing than calculated from this formula for excessively hairy yarns.

Concentration (% Solids)

The concentration of size is a critical determinant of size add-on for yarn. Add-on can be easily increased or decreased by adjusting the solids in the size formulation. Since evaporation losses may occur during slashing, particularly in creep speed operation, solids should be continually monitored in the size box. Solids can be measured with the refractometer.

Viscosity

One of the most critical variables in sizing is viscosity. A properly sized warp will have size completely encapsulating (360°) the yarn surface to hold down loose fibers. Internal penetration must be sufficient (15-25%) to anchor the size film to the surface of the yarn. Too low a size viscosity allows liquid to penetrate too deeply into the yarn. Too high a viscosity will not allow sufficient penetration to anchor the size. If ends are tightly packed in the size box, viscosity should be lowered to improve penetration. Because of considerable differences between slashing operations, the range for viscosity is too broad for a definitive recommendation. However, the importance of maintaining consistency in viscosity cannot be overemphasized. Viscosity can be checked with a Zahn cup. The size of the cup should be chosen to allow for the entire liquid to flow from the cup in 7-15 seconds.

Size Box Temperature

The size box temperature is important for controlling viscosity of the size solution. Temperature also affects the ability of the size to wet the fibers. High temperatures may cause polyvinyl alcohol to form skin, causing hard size formation when the slasher is stopped or is in creep speed. The recommended temperature range is 160-185 °F.

Squeeze Roll

Squeeze roll pressure can be adjusted to change size wet pick up (WPU) but the preferred method of adjusting WPU is to change the solution concentration. Roll pressure can vary from 10-50 psi. In addition to pressure, the hardness of roll, the weight of roll and the composition of roll will affect WPU.

Drying

Slasher cans should be coated with fluorinated resin and be free of burrs, ridges and other imperfections. Sticking sometimes occurs on worn coatings. If this happens, the addition of a small amount of release agent to the size formulation will eliminate sticking. Since most release agents act as humectants, their use is not recommended except in emergency conditions.

In Table 6 a conversion chart is provided for determining drying can temperature from steam pressure reading. The first drying can should be operated at a relatively low temperature (250-270 °F, 121-132 °C) to avoid sticking with the resultant film formation on the drying cylinders. This film could damage the sizing on the yarn. As a cautionary note, too low a temperature can also lead to sticking.

Drying temperatures are limited by fiber drying characteristics. In general, drying can temperatures should be set at the minimum required to dry the yarn to the

TABLE 6
Saturated Steam Pressure/Temperature Conversion Table

Temp.			Temp.		
°F	°C	PSIG	°F	°C	PSIG
212	100	0	310	154	63
220	104	3	320	160	75
230	110	6	330	166	88
240	116	10	340	171	103
250	121	15	350	177	120
260	127	21	360	182	138
270	132	27	370	188	159
280	138	35	380	193	181
290	143	43	390	199	206
300	150	52	400	204	233

desired moisture content, normally 5-8%. Automatic control is recommended.

When using multiple size boxes, the ends from each box should be dried separately before coming together. This prevents cementing when sheets join, insuring an easy yarn break at the bust-rods.

Stretch

Yarn stretch can vary from 1-6%, depending on loom and yarn. For polyester-cotton fiber blends, the recommended stretch is 1-1.5%. The recommended stretch is higher (3-5%) for rayon and acrylic yarns. A uniform stretch from section beam to section beam throughout the warp must be maintained.

Leasing

Good leasing requires separation of adjacent ends without damaging the size coating or the yarn. Nicks, scratches and burrs on lease rods can affect split.

Size Yarn Analysis and Testing

Sampling

Yarn testing results are only as good as the sample taken. Probably the most common source of erroneous yarn analysis data is inconsistent or irrelevant sampling techniques. The most convenient place to obtain a yarn sample for testing is at the end of the warp as it comes from the slasher. Depending upon the rate of deceleration of the slasher and the distance the yarn travels from the size box to the sample point, the sample taken may have come through the slasher at full speed, creep speed or anywhere in between.

The only way to be certain that the sample is representative of the trial is to assure that it is taken at normal running speed. This can easily be done by using a fugitive tint in a spray bottle to mark the warp just as it comes out of the size box at normal speed. The mark could also be used in conjunction with the yardage clock to measure the distance the yarn travels from the size box to the sample point. This measurement would allow calculations of the deceleration necessary to avoid having to unwrap the warp beam for proper sampling.

An alternative method of sampling is to obtain a single end sample while the slasher is running. While the full-width sample is necessary to compensate for yarn variability in most tests, it has been found that yarn hairiness measurements are less variable. The single end sampling technique makes yarn hairiness testing more convenient by eliminating the need for tying successive ends together to obtain sufficient sample length.

A critical part of sampling that is often overlooked is the unsized yarn sample. The quality of the unsized yarn weighs heavily in the performance of sized yarn. For this reason, typical evaluations compare the breaking strength, elongation and hairiness of sized yarns to the unsized yarns. It is very important to obtain an unsized sample that is most representative of the sized yarn sample being taken.

To ensure consistency in yarn test results, yarn testing is conducted in constant temperature and humidity environments.

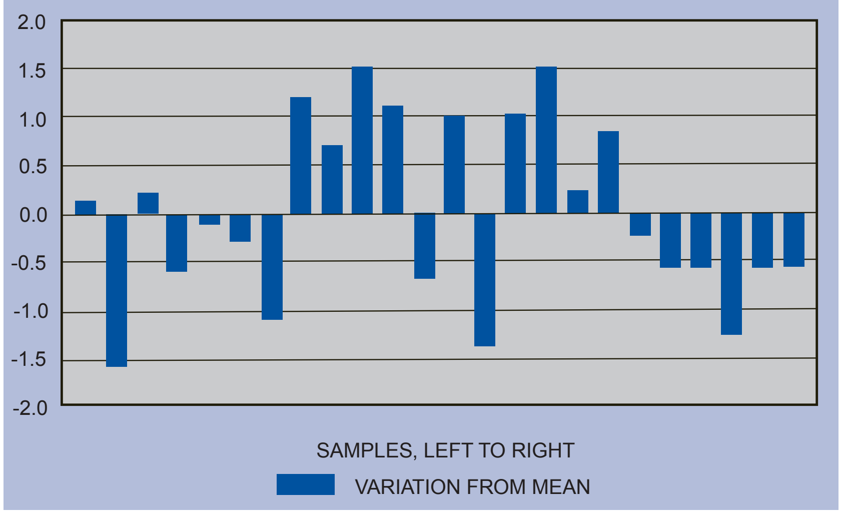
Desize Testing

By far the test performed most frequently is called “desize” or removal of size from the yarn to determine the amount applied or “add-on” based on weight percent. The major considerations naturally conflict, one to apply enough size to ensure adequate performance on the loom and the other to use as little size as possible in order to minimize costs.

The desize test is also a useful tool in measuring the consistency from shift to shift of slashing operations, and the uniformity of size application from side-to-side on the slasher. Figure 6 displays an example of side-to-side variation in size add-on.

The desize test results can be used to

FIGURE 6
Illustration of Side-to-Side Add-on Variation



detect changes in running conditions and mechanical problems, and to measure the effects of changes in raw yarn, size formulations, machinery and styling on size usage.

Size add-on is expressed as the percent by weight of dry sizing material added to the dry unsized yarn. Figure 7 contains a flow chart illustrating the steps leading to the "% add-on" calculation.

Specific laboratory procedures for desizing vary greatly between laboratories, since most procedures were handed down from individual mills where tests were developed to meet specific needs or to simulate actual mill desize operations.

Table 7 lists various desizing chemicals used and their applications. The severity of the desizing conditions needed in the laboratory will depend on the origin of the fiber, the type of sizing material used, and the type of desizing equipment used. In the cases where methods were developed to simulate actual mill conditions, construction of the woven fabric is also a factor.

Depending on the test method used, error within the method can cause as much as 1% difference in results. This should be considered when comparing results. Running duplicate tests on all samples is good practice, and a series of tests should be performed and analyzed following mechanical or formulation changes in order to verify initial results. To assure the quality of results, a control limit should be in place to require repeat testing if the difference in duplicate results is above that limit. At Celanese, we use a control limit of 0.6%.

TABLE 7
Common Laboratory Desize Chemicals

Chemicals	Applications
Water	Partially Hydrolyzed PVOH
Sodium Hydroxide	Oils, Waxes
Hydrochloric Acid	Starch
Enzymes	Starch
Solvents	Oils, Waxes
Wetting Agents	Speed Desize
Peroxide	PVOH

FIGURE 7
Percent Add-On Calculation Steps

A = Weight of Sized Sample

B = Weight of Unsized Sample

$C_{A,B}$ = Weight of Sample $_{A,B}$ After Extraction

S = Sized Yarn, % Extractables = $\frac{A - C_A}{A} \times 100$

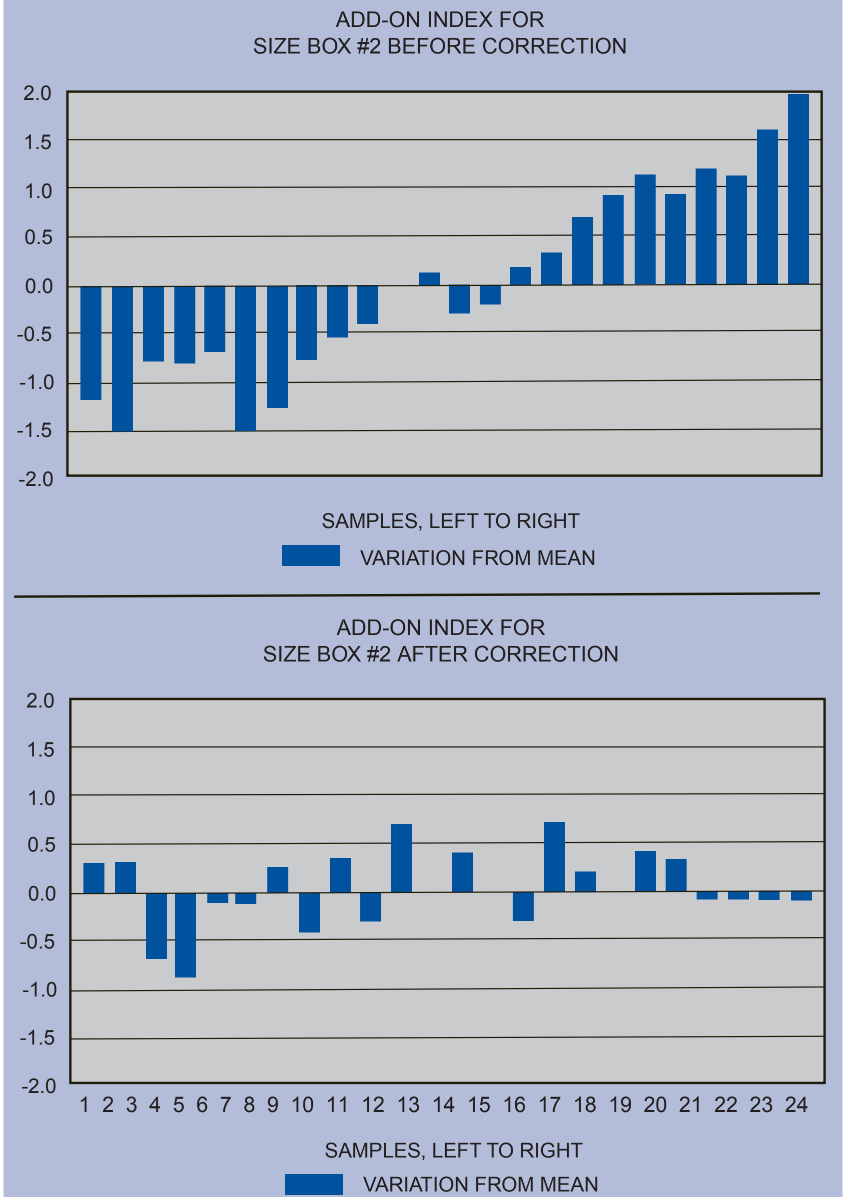
U = Unsized Yarn, % Extractables = $\frac{B - C_B}{B} \times 100$

% Added Size
= S - U

% Size Content
$= \frac{S - U}{100 - U} \times 100$

% Size Add-On
$= \frac{S - U}{100 - S} \times 100$

FIGURE 8
Before and After Add-on Index Comparison



Near Infrared Analysis

Once a desize analysis history is developed for a customer, Near Infrared Reflectance Analysis can be used to generate a calibration model to convert testing from the typical wet desize method to a Near-Infrared scanning test. This speeds results and minimizes test error.

Using the Near-Infrared technique, Celanese developed the “Add-On Index” to measure actual add-on variability in the size box. This method can detect several mechanical problems and squeeze roll imperfections which may escape detection using standard nip impression or side-center-side wet desize analysis. Figure 8 shows Add-on Index results before and after correction of a problem.

The test requires a full-width, running speed sample from each box on the slasher. Because of the speed of the Near-Infrared scanning technique, the full-width sample can be tested at three-inch intervals over the width of the sample.

For example, instead of three data points from a typical side-center-side wet desize analysis, the Add-on Index would provide 40 data points per size box on 120-inch warps.

Size Application Quality

Once the amount of size applied has been quantified, it is important to determine the location of the size in and around the yarn structure. This can be done by selectively staining the sizing material on a cross-sectional cut taken from the sized yarn and using a standard microscope. An alternative but more expensive method is electron microscopy. The advantage of the electron microscope is that a large number of yarns can be evaluated at the same time. The advantage of the standard microscope is its practicality.

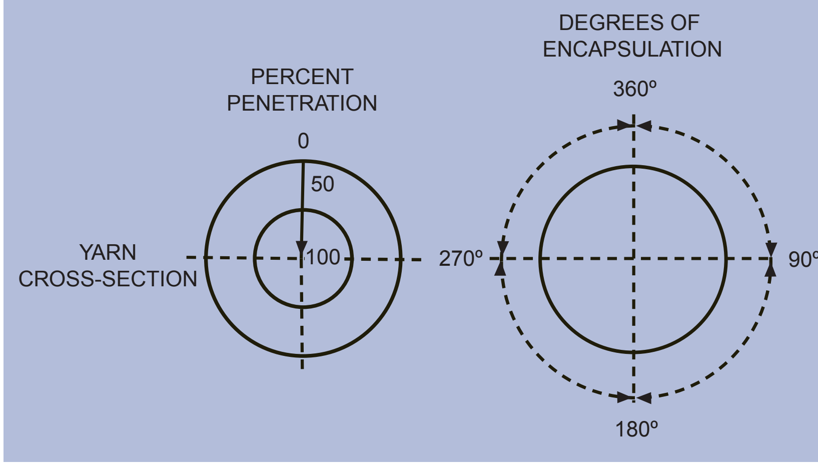
The sizing material should provide a smooth coating around the yarn surface and penetrate the yarn bundle enough to achieve good mechanical bonding. Therefore, size application quality is a combination of two parameters: size encapsulation and size penetration.

Size encapsulation is a measure of the degree of encirclement of the size around the yarn bundle. When the sizing material completely surrounds the yarn, the measurement would be 360 degrees or complete encapsulation, which is believed to be the ideal condition for optimum abrasion resistance and weaving performance.

Size penetration is evaluated by measuring the distance the sizing material has penetrated into the yarn bundle as a proportion of the yarn radius. A good general range for optimum size penetration would be 15-25%. The poor mechanical bonding resulting from low size penetration could lead to poor abrasion resistance and excessive shedding on the loom. Conversely, excessive penetration of sizing could result in yarns that are too brittle or stiff to weave on the loom.

To make a cross-section, the sized yarn sample is first embedded in a polyamide resin using a bullet mold. The embedded sample is then placed on the cutting stage of an OR/Reichert microtome and cut with a stainless steel blade. Sample thicknesses vary from 15 to 30 microns depending on the coarseness and fiber content of the yarn. Several ends from each yarn sample are tested, and the cross-sections are selectively stained using boric acid and iodine. The yarn cross-section is divided into the four quadrants of a circle. Each cross-section quadrant is evaluated for size penetration and encapsulation utilizing computer measurement software. The quadrants from all cross-sections for a given sample are then averaged for the test results. Figure 9 gives an illustration of the determination of size penetration and encapsulation values. Figure 10 is an actual cross-sectional photograph showing the stained sizing material.

FIGURE 9
Illustration of Size Penetration and Encapsulation



Single End Tensile Tests

As stated earlier, breaking strength and elongation at break for a sized yarn sample are normally compared with respective data from a matching unsized yarn sample. Instron tensile strength and elongation are determined on a random sampling of 40 ends each from the unsized and sized samples.

Care must be taken in handling the unsized yarn to avoid loss of twist prior to testing, which would affect test results. For this reason, unsized yarns are taped in place at each end of the appropriate test length prior to testing. For both the sized and the unsized yarn, care must also be taken to avoid premature stress on the yarn, which would increase breaking strength and decrease elongation.

The application of sizing to raw yarn will normally decrease the coefficient of variability (COV) of the yarn.

FIGURE 10
Actual Cross-Section Photograph Showing Stained Size

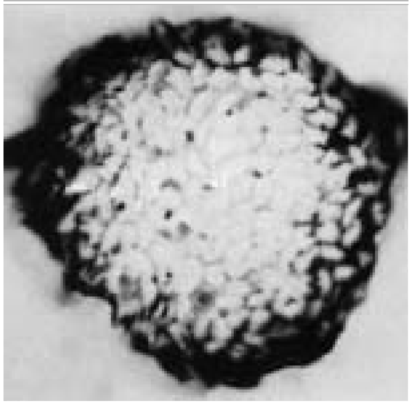


Table 8 shows an example of the Instron output after 20 ends are tested. This data should be reviewed and qualified in two ways. First, the COV for the sized yarn should be lower than the COV for the unsized yarn, If not, the test should be repeated. In Table 8, the COV for sized yarn breaking strength is 11%. If the unsized sample were tested, we would expect a COV above 11%.

Second, the maximum and minimum values should be reviewed. A general rule of thumb is that a result should be disregarded if it lies more than one standard deviation unit outside the rest of the sample population. In the case of Table 8, the data is acceptable.

It is important to note that it is generally expected for yarns to lose elongation during the sizing operation due to stretching while the yarn is wet. For ring-spun yarns, as much as 30% of the original elongation may be lost during normal sizing operations. Generally, elongation loss exceeding 30% usually warrants better stretch control on the slasher. However, open-spun-yarns and air-jet-spun yarns undergo a compacting effect whereby the change in elongation is negligible and may even appear to be an increase in elongation.

Since the yarn requires residual elongation in order to weave successfully, elongation loss should be monitored and controlled as necessary through slasher conditions. Based on general test data generated, it is recommended that the absolute minimum size yarn elongation should not be allowed to fall below 4.5%.

TABLE 8
Typical Strength and Elongation Results

Sample Number	Peak Load GF	Peak Strain %	SP
1	394.3	7.434	BK
2	360.6	7.872	BK
3	397.7	8.296	BK
4	482.8	9.081	BK
5	396.2	7.620	BK
6	374.7	7.656	BK
7	461.7	8.674	BK
8	336.8	6.535	BK
9	454.9	8.756	BK
10	376.3	7.153	BK
11	478.5	8.599	BK
12	361.0	6.834	BK
13	374.7	7.375	BK
14	361.9	7.375	BK
15	355.4	5.502	BK
16	358.2	7.592	BK
17	360.6	7.196	BK
18	402.6	8.385	BK
19	419.7	7.588	BK
20	421.3	8.465	BK
Mean	396.5	7.704	
N	20.	20.	
STD	43.61	.8576	
COV	.1100	.1113	
MIN	336.8	5.502	
MAX	482.8	9.081	

Yarn Hairiness Testing

It is important for the sizing material to coat the yarn surface well enough to slick down the "hairs" or fibers protruding from the yarn bundle. The greater number of hairs, the greater the tendency to form a size bridge between ends on the slasher, leading to a harder break at the lease rods, and the greater the amount of friction on the loom, resulting in excessive end breakage. Therefore, it is expected that sized yarns with less hairs would weave better on the loom. Warp yarn hairiness reduction is especially critical for air-jet weaving. Hairy warp yarns will cling during the shedding process and knock down the pick on an air-jet loom.

A Shirley hairiness meter is used to measure yarn hairiness, with an electronic sensor "counting" hairs that exceed three millimeters in length. The Celanese test procedure measures the hairiness level of unsized and sized yarn, reports the actual result, and calculates the percent reduction in hairiness. Percent reduction in hairiness is another indicator of size application quality.

Summary

The preceding discussions involved several tests, not one of which alone can be conclusively related to weaving performance. However, the tests give measurements of critical factors affecting weaving performance, and an overall evaluation considering all of the test results can therefore be valuable.

Glossary of Textile Industry Terms

Abrasion – Rubbing of the yarn on the loom, generally caused by contact of the yarn with adjacent yarns on the loom, metal parts of the loom, or the shuttle or projectile. Sizing materials are generally formulated to protect the yarn from these forces of abrasion.

Acetate fiber – A manufactured fiber made from cellulose acetate.

Acrylic fiber – A manufactured fiber made from a polymer primarily composed of acrylonitrile units.

Acrylic binder – A liquid solution of an acrylic resin; a sizing additive normally used to increase adhesion to synthetic fibers.

Acrylic resin – A resin produced from acrylic acid derivatives.

Add-on – A measure of the amount of sizing material applied to warp yarn, usually expressed as a percent of the weight of the bone-dry yarn before sizing.

Add-on Index – A measure of the variation in size add-on at continuous intervals spanning the width of the warp shed or size box. Near Infrared Reflectance Analysis is used to obtain individual data points for the Add-on Index.

Adhesion – In sizing, adhesion is the attractive force between the sizing material and the warp yarn.

Air-jet loom – A process which uses jets of air to propel and support filling yarn across the width of the weaving machine.

Air-jet spun yarn – A yarn manufacturing process which uses currents of air to "spin" fibers together into yarn.

Antistat – As a sizing additive, any chemical which would reduce the amount of static build-up on the slasher or weaving machine.

Antifoam – An additive used in sizing formulations to prevent foam from occurring.

Binder – As a sizing additive, any chemical which would enhance the adhesive properties of the sizing formula to the warp yarn.

Bullet mold – An aluminum mold used to embed yarn samples in resin for subsequent cutting of cross-sections.

Bust rods – Metal rods in the leasing section of the slashing machine which separate the yarns after application and drying of the sizing material.

Caustic – Sodium hydroxide, usually used in dilute solutions to remove sizing from yarn.

Conditioning; preconditioning – Treatment of samples prior to testing requiring equilibration of the samples in a maintained standard atmosphere for a specified period of time. For most textile testing, conditioning is performed in a standard environment of 68-72 °F and 63-67% relative humidity.

Count, yarn – See Yarn count.

Count, fabric – A measurement of the density of the fabric, where the number of ends per inch is added to the number of picks per inch to obtain the fabric count. For example, if a percale sheet has 110 ends per inch and 70 picks per inch, the fabric count would be 110 + 70, or 180.

Creel; section beam creel – A structure designed to hold multiple section beams for combination into warp sheds on the slasher.

Cross-section – A section of yarn cut at a right angle to its length.

Crown; crowned roll – The curvature of a rubber squeeze roll, formed during manufacturing of the roll, which allows pressure to be evenly distributed across the roll at a given pressure loading at the ends of the roll.

CV; COV; Coefficient of Variation – A relative measurement of precision which is obtained by dividing the standard deviation of a series of measurements by the average of that series of measurements. It is usually multiplied by 100 and expressed as a percentage (CV%).

Defoamer – An additive used in sizing formulations to reduce generated foam.

Desizing – Process for removal of sizing from yarn or fabric.

Dry can; drying cylinder – Cylinder containing pressurized steam upon which yarn is threaded for the purpose of drying the yarn after application of sizing material on the slasher.

Electron microscopy – The use of an electron microscope to study materials. Using electron microscopy, one can obtain images at high magnifications of surface phenomena on yarn or fabric.

Elongation; elongation at break – The distance which a yarn can be stretched before breaking, usually expressed as a percentage increase over its original length.

End – A single yarn.

Filling yarn – Yarn which is inserted across the width of a weaving machine.

Greige cloth (pronounced "gray" cloth) – Cloth which has not been treated by any other textile process (such as desizing, bleaching, finishing, etc.).

Ground warp – The warp yarn which is combined with pile warp to produce a pile fabric, such as terry. The ground warp forms the foundation of the fabric, while the pile warp forms the pile.

Hairiness; yarn hairiness – A measurement of the number of hairs per unit length on a sized or unsized yarn. Typically, fibers which protrude 3mm or more from the yarn surface are counted as "hairs" when evaluating yarn hairiness.

Heatset; heatsetting – The application of heat to fabrics, particularly those composed of synthetic materials, to enhance the dyeability of the fabric and minimize dye variation.

Humectant – An additive in a sizing formulation which enhances the absorption of moisture.

Humidity – A measure of the amount of moisture in the air.

Hydrolysis – A measurement of the number of hydroxyl units along the polymer chain of polyvinyl alcohol, expressed as percent.

Instron – An instrument used to measure breaking strength and elongation of yarns and fabrics.

Kettle wax – A solid wax, usually derived from animal fats, which is added to the sizing cook kettle, hence the name "kettle wax".

Lease – The separation of yarns so that they may be properly tied in on a loom. Proper leasing will separate all of the yarns travelling through one dent in the comb at the front of the slasher.

Leasing section – A series of bust rods at the front of a slasher which accomplishes separation of yarns after sizing.

Loom – An automated weaving machine.

Loom beam – A beam of yarn from the slasher, which is now ready for weaving.

Lubricant – An additive in a sizing formulation which enhances the lubricity of the dried sizing material on the yarn, thereby reducing sticking during the drying process and avoiding clinging of yarn to machine parts and other yarns on the loom.

Microtome – A device used to hold sample specimens for cutting with a sharp knife, such as the preparation of yarn cross-sections.

Muslin sheeting – A plain weave fabric with a count of at least 128 yarns per square inch.

Near infrared – An instrument used to scan samples for the purpose of quantifying a given parameter, such as percent add-on. The near infrared region of the spectrum is outside the visible region and comprises wavelengths from 660 to 2500 nanometers.

NIRA – Near Infrared Reflectance Analysis, which is one application of near infrared technology.

Nylon fiber – A manufactured fiber made from a polymer primarily composed of amide linkages.

Open-end spinning – A yarn manufacturing process whereby sliver is spun directly into yarn, eliminating carding and roving operations.

Oxford shirting – A soft, porous fabric made using a modified plain or basket weave. Frequently dyed yarns are incorporated in the warp to produce stripes.

Percale sheeting – A plain weave fabric with a count of at least 180 yarns per square inch.

Pick – A piece of yarn in the weft direction of the woven fabric; the insertion of one filling yarn between the sheds of a weaving machine (e.g., 500 "picks" per minute).

Pile warp – The warp yarn which is combined with a ground warp to produce a pile fabric, such as terry. The ground warp forms the foundation of the fabric, while the pile warp forms the pile.

Polyamide – A synthetic polymer consisting of a chain of amides.

Polyester fiber – A manufactured fiber made from a polymer primarily composed of an ester of a substituted carboxylic acid.

Polyester binder – A liquid solution of a polyester resin; a sizing additive normally used to increase adhesion to synthetic fibers.

Polyester resin – A resin produced by polymerizing a hydroxy-carboxylic acid or by forming a condensation product between a dihydroxy alcohol and a dicarboxylic acid.

Pre-drying – In the case of a multiple-box slasher, pre-drying is accomplished by locating drying cans above the size boxes for the individual warp sheds. After pre-drying, the sheds of yarn come together for final drying on a separate set of drying cans. Adequate pre-drying is required to keep yarns from different sheds from sticking together while drying is completed.

Preparation – A process performed on textile goods to ready them for dyeing, finishing or printing. Processes included in preparation of greige cloth typically include singeing, desizing, scouring and bleaching. Other preparation processes, such as mercerization, may be included, depending on the greige fabric and its end use.

Rapier loom – A weaving machine which uses two flexible steel tapes to guide yarn through the sheds. One tape carries the yarn to the middle of the machine where it is transferred to the other tape.

Rayon fiber – A manufactured fiber made from regenerated cellulose.

Refractometer – An instrument, typically hand-held, which is used to indirectly measure the amount of solids in a solution. The instrument channels light through a chamber where it is refracted by the liquid being tested and then reflected to a graduated "window". The instrument is calibrated to convert the amount of refraction to percent solids.

Ring spinning – A system of spinning yarn from roving sliver.

Section beam – A beam of yarn loaded on the creel of the slasher for the purpose of sizing. Several section beams are required to make each warp beam, depending on the sley of the fabric to be produced.

Selvedge – The edge of the fabric at the sides of the loom as the fabric is woven.

Shed; warp shed – The opening formed when warp yarns are separated to insert filling yarn on a weaving machine.

Shedding – The separation of size film or broken fibers from the main body of the yarn.

Shirley hairiness monitor – An instrument designed to measure yarn hairiness by using an electric "eye" to count the number of hairs protruding a given length from the surface of the yarn.

Shuttle loom – A weaving machine in which the filling yarn package is transported back and forth through the shed during weaving by means of a shuttle.

Size add-on – See Add-on.

Size box – The vessel which holds the sizing solution and applicator assembly (squeeze rolls) on the slasher.

Sizing – Material applied to warp yarn to protect it from breakage and abrasion during weaving.

Sizing blend – A blend of sizing materials in one package.

Slasher – Machine used to apply sizing material to warp yarns.

Sley – Moving part on a loom which carries the reed; number of ends per inch in a fabric construction.

Spin finish – Material composed of antistats and/or lubricants which is applied to synthetic fibers to improve processing in spinning.

Squeeze roll – Rubber roll, typically made of acrylonitrile, which squeezes the yarn on the slasher to remove excess sizing solution.

Staple – A mass of fibers having the same physical characteristic, typically length.

Starch – A complex carbohydrate derived from plants. Typical starches used in textile sizing are corn and potato starches and their derivatives.

Taper, tapered roll – A simulation of a crowned roll where the diameter of the squeeze roll increases from the sides to the center at a standard slope. Tapering is a short-cut attempt to crown the roll, but without consistent lengthwise curvature, squeeze pressure is not evenly distributed across the roll at a given pressure loading at the ends of the roll.

Terry – A fabric made from ground and pile warps, where the pile is in the form of loops, such as in bath towels and bath mats.

Tex – A measurement of yarn size using a direct numbering system. The unit of Tex expresses the mass in number of grams of 1 kilometer of yarn.

Viscometer; Brookfield viscometer – An instrument which measures the viscosity of a liquid by quantifying its resistance to shear.

Viscosity – A measure of thickness of a liquid, either by resistance to flow or resistance to shear.

Warp; warp beam – A beam of yarn produced on the slasher.

Warp density – The number of ends per inch in the size box.

Wax – See Kettle wax.

Waxless size – A sizing material formulated with synthetic lubricants to replace typical kettle wax.

Weaving – The process of making fabric from yarn.

Weft – Yarn in the width direction of a fabric as it is woven.

Yarn – A strand of fibers, usually twisted or entangled together for strength.

Yarn count – A measurement of yarn size using an indirect yarn numbering system. For example, cotton count is a numbering system which indicates the number of hanks in one pound of yarn, where a hank equals one 840-yard length of yarn.

Zahn cup – A steel cup of standard volume which is used to measure the viscosity of a liquid by quantifying its resistance to flow. Liquids are timed as they flow through a hole in the bottom of the cup. A variety of standard hole sizes are available, and cup selection depends on the thickness of the liquid being tested.

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